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(54) Method for detecting and controlling the dynamic unbalance in a drum of a washing machine and washing machine that uses such method

(57) A washing machine comprises accelerometers or optical means which are directed along a direction that is sensitive to the effect of a load which is dynamically unbalanced. Such direction is preferably a direction parallel to the axis of rotation of the drum.

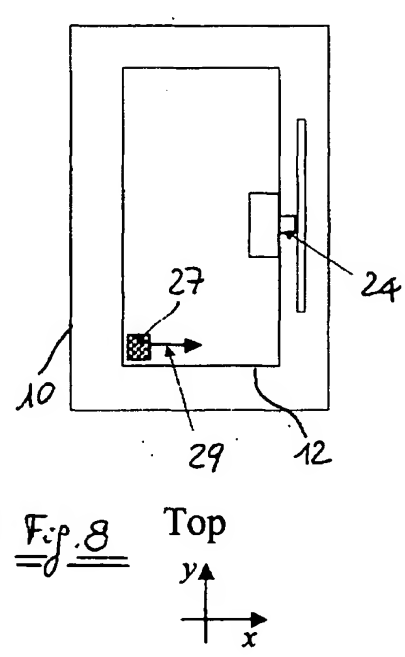

Fig. 8

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Description

[0001] The present invention relates to washing machines, particularly of a type having a perforated drum rotating about a horizontal axis. With the term "horizontal axis" we mean all the washing machines having an axis of the drum substantially horizontal, tilted axis washers being included. With the term "washing machine" we mean all the kinds of appliances for washing clothes and the like, washer-dryers included. With reference to Figures 1 and 2 a washing machine has an outer housing (cabinet) 10 which is floor standing. A tub 12 is suspended in the housing by means of a suspension system comprising springs 14 and dampers 16. The tub 12 is a non-rotary device containing a perforated drum 18 that is supported by one or two bearings. The drum 18 is rotated by an electric motor 26. The transmission system comprises a belt 20 connecting a pulley 22 mounted on the drum shaft and the motor shaft 24 directly. The motor 26 is equipped with a drive system and, often, with a tachometer generator that can measure the rotational speed of the motor shaft. In electronic controlled machines, the command to the motor drive system is decided on the basis of the difference between the command (desired) speed and the actual one as read by the tachometer.

[0002] It is well known that vibrations are an important issue in washing machines. They can become very large in the spinning phase when the drum is accelerated from a low speed (around 100 rpm), at which the laundry is retained against the drum wall by centrifugal force to a high speed that can vary from 600 to 1600 rpm according to the different washing machines. In order to avoid an undesired excessive vibration level, a distribution phase is often carried out. In this phase the drum speed is incremented according to a certain law, up to the speed at which the laundry is retained in a fixed position relative to the drum by centrifugal force. The purpose of this phase is to evenly distribute the laundry in such a way that there is no remaining unbalance acting on the drum.

[0003] Due to the presence of a large single article (such as a bath towel) or concentrated loads (e.g. a pair of tennis shoes), it may happen that a certain amount of unbalanced load remains inside the drum.

[0004] In figures 3 and 4 a schematic view of the front and the lateral side of the rotating drum is shown. An orthogonal tri-dimensional reference system that is coherent with that in figure 1, is also shown in between the two figures 3 and 4.

[0005] In the following description, we shall call static unbalance the unbalance created by a load of laundry L such that the center of gravity of the oscillating system G does not coincide with the geometrical center D of the drum. This configuration creates an eccentricity in the movement of the drum. In mechanics, this kind of unbalance is called "static", because it is sufficient a static balancing of the forces acting on the drum to equalize the unbalance.

[0006] It is well known in the art that if a rotating machinery subject to this kind of unbalance is rotated at a constant speed in a vertical plane, it exhibits an oscillating behavior in terms of both angular speed and motor torque applied to the shaft. This can be understood in a very simple way by thinking of the torque generated by the unbalanced load weight whose value is oscillating according to the angular position of the laundry L.

[0007] Therefore, it is relatively simple to detect the static unbalance by measuring for instance the speed fluctuations during a constant speed phase. This method is disclosed in EP 0 071 308 that relates to method for determining the amount of (static) unbalance. Such method comprises providing a constant command speed to the motor control algorithm, monitoring the actual motor speed as measured by a tachometer generator and looking at the changes of the speed. Variations by more than a certain amount indicate the presence of a severe unbalanced load. On the same principle are also based EP 0 969 133 A1 and GB 2 326 947 A.

[0008] Another known method for detecting the amount of static unbalance is to check either the translational displacement or the translational acceleration of the tub along either the y or the z-axis. In EP 0 879 913 A1, for instance, the relative displacement between the cabinet and the tub is detected by measuring the pressure variation inside a cylindrical hollow body connecting the cabinet to the tub.

[0009] Referring now to Figure 4, the disposition of the laundry inside the drum is such that the center of gravity of the rotating system G coincides with the geometrical center of the drum. However, if the drum is rotated, a centrifugal force acts on the laundry. In particular, the components F_1, F_2 along the z-axis, generate torque acting on point G. Such a torque is directed along the y direction. For reasons of symmetry, the same thing happens along the z-axis (this can be observed if one looks at the top view instead of the lateral one). Summarizing, the dynamic unbalanced load generates an instantaneous torque whose direction lies on the y-z plane and no resultant torque acts on the x-axis.

[0010] This means that, when the drum rotates at constant speed, no fluctuations can be seen in terms neither of speed nor of motor torque. So, the standard known methods of unbalance detection fail.

[0011] However, considering a constant drum speed, due to the presence of dynamic unbalance, there is a forcing action that excites the two rotational modes along the y and z-axis.

[0012] Therefore, the presence of the dynamic unbalance may be dangerous for two reasons. Firstly, when the natural frequencies related to the rotational modes of the oscillating mass are crossed, an excessive unbalance can make the machine walking and/or hitting according to the damping coefficients of the suspension system in those directions. Secondly, a dynamic unbalanced load can generate large vibrations during the constant high speed-spinning phase.

[0013] Acting on the characteristics of the suspension system, the designer can change the repartition of the effects

between the tub and the cabinet, but the overall energy provided to the system by the rotating dynamic load cannot be modified.

[0014] The present invention proposes a different approach. The amount of dynamic unbalance is detected and the decision of crossing the rotational critical frequencies is taken according to this information. Furthermore, the spinning speed can be chosen on the basis of the sensed unbalance.

[0015] It could seem that a pure dynamic unbalance configuration is a very special one and that its occurrence is very limited. Indeed, it is true that a certain amount of static unbalance is often present, but it is also true that the more probable case is given by the combination of both static and dynamic unbalance.

[0016] Therefore, a method that put together a static detection along with a dynamic one can obtain the best results.

[0017] For a better understanding of the invention, we will refer to the following drawings in which:

- Figures 1 and 2 illustrate a schematic drawing of a conventional washing machine with a drum that can rotate along a horizontal axis;
- Figures 3 and 4 show both the front and lateral projection views of the drum in presence of static (figure 3) or dynamic (figure 4) unbalance;
- Figure 5 is the speed profile used in a first embodiment of the method according to the invention;
- Figure 6 is the speed profile used in a second embodiment of the method according to the invention;
- Figures 7 and 8 show an example of how to mount an acceleration sensor on the tub of the machine to detect tub vibrations;
- Figures 9 and 10 report the accelerations measured by an accelerometer mounted as shown in figures 7 and 8, where figure 9 refers to a low dynamically unbalanced laundry, whereas figure 10 to a high one;
- Figures 11 and 12 show an example of how to mount an optical displacement sensor for sensing the tub movements;
- Figures 13 and 14 report the displacements measured by an optical sensor mounted as shown in figures 11 and 12, where figure 13 refers to a low dynamically unbalanced laundry, whereas figure 14 to a high one;
- Figure 15 and 16 illustrates a method for mounting an optical displacement sensor in such a way that it is possible to perform a self-calibration procedure and the same sensor can be used also for detecting the position of the door in a top loading machine;
- Figure 17 shows the flow chart associated to one embodiment of the method according to the present invention; and
- Figure 18 illustrates the flow chart associated to another embodiment of the method according to the present invention.

[0018] In the washing machine according to the present invention, the spinning cycle comprises different steps. With reference to Figure 5, in phase A the drum is accelerated from zero to a low speed (around 50rpm) at which the peripheral acceleration of the laundry is below 1 g, so that the load is continuously falling down into the drum. Afterwards, a so-called distribution phase B is performed. The drum is driven up to the speed at which the load is retained in a substantially fixed position relative to the drum by centrifugal force, so that the load is no more allowed to fall down. In many cases a further constant speed phase C is carried out. Usually, if an unbalance detection algorithm is present, it works during this phase. The amount of static unbalance is checked by looking either at the drum/motor speed or the motor torque. The chosen constant speed s_0 is usually around 100rpm.

[0019] At the end of this phase, the controller can decide whether to accelerate the drum up to a high speed at which the water in the laundry can be extracted, or to stop and restart the spinning phase. This decision is taken on the basis of the measured static unbalance. If the spinning phase is abandoned, the load falls down and the washing machine makes a new attempt to better distribute the clothes.

[0020] According to the present invention, in order to control the amount of dynamic unbalance in the laundry, some other steps are added after the static unbalance check. In the following, the way of detecting the dynamic unbalance is explained without entering into details regarding the sensors, but generally speaking of measured quantity (as acceleration, velocity or displacement). This approach is used to point out the fact that the algorithm is independent on the particular sensor. At the end of the algorithm description, a more detailed analysis of the sensors will be provided.

[0021] In a first embodiment of the method according to the invention, if the amount of static unbalance in the laundry is not too high, a constant slope drum acceleration phase E is entered (acceleration a_1). During this phase the output of the sensor is checked and the minimum and maximum read values are stored into suitable variables in the micro-controller. At each sampling instant the difference between the maximum S_{max} and minimum value S_{min} is computed and compared to a certain threshold T as it is shown in the flow chart of figure 17. In the embodiment shown in figure 12, the threshold value T may be a function of the computed inertia I (and therefore of the amount of load in the drum) and/or of the static unbalance (U). If the threshold is exceeded, then the spinning is quitted and the distribution phase is restarted (F); otherwise the drum keeps on accelerating (E). Since the maximum and minimum value are updated at each sampling period, it may happen that their difference overcome the threshold at any time instants. This is reported in figure 5 by drawing a certain number of descending lines (F).

[0022] If a certain given speed (s_1) is reached without overcoming the given threshold T, the dynamic unbalance is supposed to be low enough to allow spinning at a high speed. In this case the drum is speed up (H) with a different acceleration (a_2 that is usually higher than a_1) up to a predetermined centrifugal speed (M). It has to be noticed that s_1 should be below the critical resonance of the rotational modes, which is the speed at which the effect of the dynamic unbalanced load is maximum in terms of displacements. On the other hand, the value of s_1 should be chosen in such a way that the effect of the dynamic unbalance is detectable, namely it should not be too far from the resonance frequency. For instance, if such a resonance is at 300 rpm, a good value for s_1 could be 250rpm.

[0023] According to the present invention, the spinning speed M can be chosen on the basis of the computed dynamic unbalance measure. More precisely, the larger is the dynamic unbalance, the lower will be the chosen speed in such a way that the actual vibration level remains approximately the same in all the conditions.

[0024] The threshold for the dynamic unbalance check can be set at different values according to the detected static unbalance. Moreover, the speed s_1 can also be chosen on the basis of the inertia/weight of the laundry inside the drum that can be computed by using one of the methods well known in the art (i.e. US 5,507,054). This approach has the advantage that the designer can keep constant the difference between s_1 and the resonance frequency, independently on the inertia of the laundry.

[0025] According to another embodiment of the invention (with reference to figure 6), the speed s_1 can be kept constant for a certain amount of time K (phase P), and the difference between the maximum and the minimum of the measured variable checked during this interval. If the difference remains below a certain threshold, the drum is accelerated to the spinning speed (M); otherwise the motor is switched off and the distribution phase (A-B) is repeated. Once again the value of s_1 can be chosen on the basis of the inertia/weight of the load. This embodiment is shown also in the flowchart of figure 18.

[0026] The present invention may be well applied also in the case of washing/drying machines having a drum rotating around a horizontal axis or a vertical axis and provided with means for automatic balancing the unbalanced laundry present in the drum. In fact, it is well known that such devices work properly when the drum rotates at speed above the critical one. Moreover, at speeds below the critical resonance frequency, the behavior of these balancing systems is not perfectly known, and the total amount of unbalance (both symmetric and dynamic) is not constant.

[0027] In order to avoid an excessive amount of vibrations/walking/hitting in crossing the main resonance of the oscillating system the method explained in the present invention can be used.

[0028] According to an embodiment of the invention, an acceleration sensor 27 (figures 7 and 8) is mounted on the machine, so that vibrations along a certain axis are monitored. The sensible axis of the accelerometer must be directed along a direction that is sensitive to the effect of a dynamic unbalanced load. For example, in figures 7 and 8 the acceleration sensor is mounted on the top of the tub, with the sensible axis 29 directed as the x-axis. As already described, a dynamic unbalanced load generates an instantaneous torque that lies in the y-z plane. This torque excites the two rotational modes of vibration along the y and the z-axis. Both these two modes generate acceleration along the x direction that is the direction along which the maximum acceleration can be detected.

[0029] Another important parameter is the distance between the accelerometer 27 and the instantaneous axis of rotation of the oscillating mass (tub 12 and drum 18). Of course, the larger is this distance, the bigger are the accelerations measured. It follows that, if we assume that the instantaneous axis of rotation belongs to the y-z plane, the position shown in figures 7 and 8, maximizes the acceleration detected.

[0030] In figures 9 and 10 the measurements recorded by a commercial accelerometer in presence of two different levels of dynamic unbalanced load are shown. The sensor used in tests carried out by the applicant is produced by Analog Device and is based on MEMS technology (Micro Electro Mechanic System). It is specifically designed to work with low cost microcontroller and it is available both as 2-axis and 1-axis sensor. The washing machine has been run using the speed profile according to figure 5. Looking at the diagrams, it is clear that in the second case (figure 10), the tub accelerations are very large and they can be noticed in terms both of noise and vibrations. On the other hand, in the case depicted in figure 9, pretty small vibrations are detected. It is worth remarking that the amount of static unbalance is exactly the same for both figures 9 and 10, so that small differences can be seen in terms of speed or torque fluctuations.

[0031] On the basis of the present invention, the load of figure 10 would not be allowed to spin, so avoiding the large vibrations and possible damages to the washing machine.

[0032] According to an alternative embodiment of the invention, an optical displacement sensor is used to detect the movement of the periphery of the tub, being such a movement connected to the rotational displacement. An example of such an arrangement is shown in figures 11 and 12, where a target 30 constituted by a special kind of paper is attached to the periphery of the tub 12, the sensor probe 32 comprising a light emitter and receiver being mounted on the cabinet 10 (figure 11).

[0033] Figures 13 and 14 show the behavior of the displacement as measured by an interferometer optical sensor. The command speed profile is that described in figure 5. The presence of dynamic unbalanced laundry is clearly visible by the graphs. Figures 13 and 14 have been obtained in the same conditions as figures 9 and 10 that report the

accelerations instead of the displacements.

[0034] According to another embodiment of this invention, two optical displacement sensors can be used to detect the movements of the machine along two different axis both parallel to the y-axis and placed as close as possible to the ends of the machine. It can be seen that the difference between the displacements read by this devices is related to the amount of dynamic unbalance. We previously said that the total torque vector generated by the dynamic unbalanced load lies in the y-z plane. For sake of simplicity, we assume that such a torque is directed exactly along the z-axes. Although the center of mass of the machine does not move, the left side tends to move in a opposite direction with respect to the right one. By measuring the difference in these displacements, the amount of dynamic unbalance can be found. It is worth noticing that a pure "static" unbalance generates a symmetric movement of the left and right side so that the difference is zero and this situation cannot be confused with a dynamic unbalanced one. Of course, the closer the displacement sensors are to the sides of the machine, the more accurate the detection is.

[0035] The same rationale applies if two displacement sensors are used to measure the movements of the machine sides along the z-axis. According to a further embodiment of the present invention, a displacement sensor is used to detect the movement of one side of the machine either along the y-axis or the z-axis. In this case, means for detecting the static unbalance must be provided in order to separate the effects of the static and the dynamic unbalance (i.e. a speed fluctuation method can be used as described in EP 0 071 308).

[0036] Summarizing, the present invention refers to the use of acceleration and/or displacement measures for getting information regarding the mass of dynamic unbalanced laundry.

[0037] Although some examples are reported which refer to specific sensors, any of the sensing methodologies described in the following might be used with success.

[0038] A position, distance or displacement sensor can be used according to the present invention. This is a device able to convert a physical phenomenon such as position, distance, displacement in an electrical signal like voltage, current, frequency, pulse, etc. It can be with "contact" or "contactless". "Contact" sensor means that there is physical contact / connection between the sensor and the target. "Contactless" means that there is no physical touching between the sensor (probe) and the target (it is the referent). A list of some of these devices is reported in the following table 1, whereas table 2 shows a list of the major "contact" sensing technologies.

Table 1:

Contactless displacement sensors	
TECHNOLOGY	TARGET TYPE
Reed relay	magnetic target
Inductive	metal target
Capacitance	Any material target
Photoelectric	Any material target
Ultrasonic	Any material target
Magnetic reluctance	magnetic metal
Hall effect	magnetic target

Table 2:

Contact displacement sensors	
TECHNOLOGY	WORKING PRINCIPLE
Magneto-strictive sensor	position magnet
Linear displacement sensor (1)	inductive differential reluctance principle
Linear displacement sensor (2)	Electrical magnetically-coupled resonator formed with inductor and capacitor.
Ws Position sensor	(extension of the cable)

[0039] Some technologies will be analyzed more in detail and their use in the specific context covered by the present invention will be described.

[0040] An inductive displacement sensor can be used for detecting dynamic unbalanced load.

[0041] An inductive displacement sensor (probe) consists of four basic elements: sensor coil and ferrite core, oscillator circuit, detector circuit, solid-state output circuit. The oscillator circuit generates a radio-frequency electromagnetic field that radiates from the ferrite core and coil assembly. The field is centered on the axis of the ferrite core, which shapes the field and directs it at the sensor face. When a metal target approaches and enters the field, eddy currents are induced into the surfaces of the target. This results in loading effect, or "damping", that causes a reduction in amplitude oscillator signal. The detector circuit detects the variation in oscillator amplitude that it is displayed by solid-state output in an analog output that it is proportional between the distance of the sensor and the target. In the application according to the present invention the sensor probe can be assembled on the tub and as a metal target the cabinet itself can be used. Vice versa the target can be assembled on the cabinet and the tub is as a target. In the case the tub is made of nonmetallic material, a metal target has to be assembled on the tub.

[0042] A capacitive displacement sensor can be used for detecting dynamic unbalanced load.

[0043] A capacitive sensing is based on dielectric capacitance. Capacitance is the property of a dielectric to store an electric charge. Usually the capacitor consists of two conductive plates separated by an insulator (usually called dielectric, and it can be also the air) to store an electric charge.

[0044] The capacitive displacement sensor is quite similar to the inductive sensor. It is composed by four basic elements: sensor (conducting plates), oscillator circuit, detector circuit, and solid state output circuit. The major characteristic of capacitive sensors is that, in addition to the metallic target, it can detect also non-metallic target (dielectric material). In both capacitive and inductive sensors the amplitude variation is related to the distance between the sensor and the target. According to the invention, the sensor probe can be assembled on the tub and as target the cabinet itself can be used. Vice versa, the target can be assembled on the cabinet and the tub used as a target.

[0045] A photoelectric displacement sensor can be used for detecting dynamic unbalanced load.

[0046] Optical sensors are used to monitor displacement, position, distance, and are commercially available in a wide variety of ranges and types to meet different, application requirements.

[0047] A photoelectric sensor is based on the principle of light emission and reception and is used along with a reflective target. There are three basic configurations for photoelectric sensing:

Through-beam: the target passes between an emitting unit and a receiving one, blocking the beam.
Retroreflective: the target passes between the sensor and a reflector. The emitter and receiver are in the same housing.
Proximity-diffuse: the unit senses the light directly from the target. The emitter and receiver are in the same package, in the same manner as a retroreflective, however, the receiver is more sensitive to the weaker light which is diffused by the surface of the target.

[0048] Optical devices are contactless sensors, can work at considerable distance from the target and have large bandwidth. Laser sensor and optic sensor with optic fiber have to be also included in the list.

[0049] The application of photoelectric sensors in the present invention has been already discussed.

[0050] An acceleration sensor can be used for detecting dynamic unbalanced load.

[0051] Acceleration is an important parameter for general -purpose absolute motion measurements, and vibration and shock sensing. Accelerometers are commercially available in a wide variety of ranges and types to meet diverse application requirements. They can be configured as active or passive sensors. An active accelerometer (e.g. piezoelectric) gives an output without needing an external power supply, whereas a passive accelerometer changes its electric properties (e.g. capacitance), thus it requires an external power supply. The typical accelerometer consists of a piezoelectric disk or slices loaded by seismic masses and held in position by a clamping ring. When the accelerometer is subjected to a vibration / acceleration, the seismic mass exerts a variable force on the piezoelectric element. Due to the piezoelectric effect, this force produces a corresponding electrical charge. The most common types of accelerometers are piezoelectric, piezoresistive, differential-capacitance, strain gauge, inertial type, and induction type. The use of accelerometers for detecting dynamic unbalanced laundry has been extensively described above.

[0052] According to a further embodiment of the present invention, means for self-calibrating a displacement sensor are provided. We refer to the situation shown in figures 15 and 16 that relate to a top-loading washing machine having a door 33 on the side wall of the tub 12. The probe 34 of the sensor is assembled / fixed on the cabinet 10 and a piece of known material is attached to the tub 12 as target 36. An additional target 38 is fixed on a boss rotating with the pulley. Doing so, the displacement sensor will read the position of the tub, except the instants in which the pulley target passes in front of the probe 34. In this instants a sudden change to another voltage level is detected. This technique can be used for eliminating the sensor calibration or adjustment phase so improving the accuracy of the output. In fact, in all the devices described in the previous paragraphs, the sensor output sensitivity and linearity may strongly depend on the point at which the sensor is working inside the working range. By means of two targets 36 and 38 it is possible to well define the working range. In fact the tub target 36 is used to define the off set value while the pulley target 38

is used to define the operating range.

[0053] Now, assuming that the reflectance coefficient for both targets (target 36 of the tub and target 38 of the pulley boss) is the same, and that the distance between the tub 12 and the pulley target 38 is quite constant also for large production (namely, that the assembling tolerances are small), the difference in the sensor output measured when the pulley target 38 passes in front of the sensor probe 34 can be put in a one-to-one relationship with the distance between the tub target 36 and the pulley target 38. Since this distance is known (apart from the tolerances), any further calibration can be avoided.

[0054] Moreover, the described technique can be also used for detecting the position of a particular point of the drum. This can be useful for instance to locate the position of the door 33 in the top-loading machine as the one schematically disclosed in figures 15 and 16. A device that is a proximity switch fixed on the tub excited by a target (a permanent magnet) fixed on the pulley that corresponds to the door position is already known. Scope of this system is to operate the drum in order to stop the door 33 in up position at the end of washing process to facilitate the load extraction. At the end of the process the control detects the proximity switch and switch off the motor, consequently the drum will be stopped with the door 33 in its upper position. By using the self-calibrating technique just described, and putting the pulley target 38 in such a way that it passes from the sensor probe 34 when the drum door 33 is in its upper position, it is possible to get also this feature without adding additional sensors.

[0055] The applicant has performed tests by using commercial optical sensor VTG 2451 produced by EG&G Vagtec.

[0056] Even if the above description is mainly focused on washing machines having a horizontal axis of the drum, the present invention is not limited to this kind of washers and relates to vertical axis washers too. The applicant discovered that vertical axis washers which use a continuous circulation of washing liquor are particularly affected by dynamic unbalance mainly due to unevenness of water content of different portions of the load at different heights within the drum.

Claims

1. Washing machine, comprising detecting means for assessing acceleration and/or movement of an oscillating mass comprising at least the tub and the drum of the washing machine, such acceleration and/or movement being due to out of balance conditions of the load, **characterized in that** said detecting means is directed along a direction that is sensitive to the effect of a load dynamically unbalanced.

2. Washing machine according to claim 1, in which the x axis is the axis parallel to the axis of the drum, the y axis is an horizontal axis orthogonal to the x axis and the z axis is a vertical axis orthogonal both to x and y axis, **characterized in that** said detecting means is placed for detecting acceleration and/or movement along the x direction.

3. Washing machine according to claim 2, **characterized in that** said detecting means is placed at the maximum distance with reference to the instantaneous axis of rotation of the oscillating mass.

4. Washing machine according to anyone of claims 1-3, **characterized in that** said detecting means comprises at least one accelerometer.

5. Washing machine according to any of claims 1-3, **characterized in that** said detecting means comprises a sensor selected in the group consisting of position, distance and displacement sensors.

6. Washing machine according to claim 5, **characterized in that** an optical displacement sensor is used either for assessing the dynamic unbalanced load or for sensing the position of the drum.

7. Washing machine according to claim 6, **characterized in that** the optical displacement sensor can be self-calibrated.

8. Washing machine according to any of the previous claims, **characterized in that** it comprises means for automatic balancing the statically unbalanced laundry present in the drum.

9. Method for detecting out of balance conditions in a drum of a horizontal axis washing machine, characterized it comprises the step of determining the acceleration and/or movement of an oscillating mass comprising at least the tub and the drum of the washing machine along a predetermined direction that is sensitive to the effect of a load dynamically unbalanced.

10. Method according to claim 8, **characterized in that** it comprises the steps of:

- accelerating the drum at a first predetermined rate from a given speed at which the load is retained in a substantially fixed position relative to the drum by centrifugal force up to a given speed below the critical speed of the oscillating mass,
- accelerating the drum at a second predetermined rate thereby crossing the above critical speed up to a given spinning speed.

11. Method according to claim 9, **characterized in that**, before the second acceleration step, the drum is rotated at a constant given speed, the assessment of the dynamic unbalance being carried out during such step.

12. Method according to claim 9, **characterized in that** the spinning speed is set according to the assessed value of dynamic unbalance of the load.

13. Method according to claim 11, **characterized in that** the assessment of dynamically unbalanced load is carried out with reference to a predetermined threshold value, such value being related to the detected static unbalance.

14. Method according to claim 12, **characterized in that** the above threshold value is also related to the amount of load.

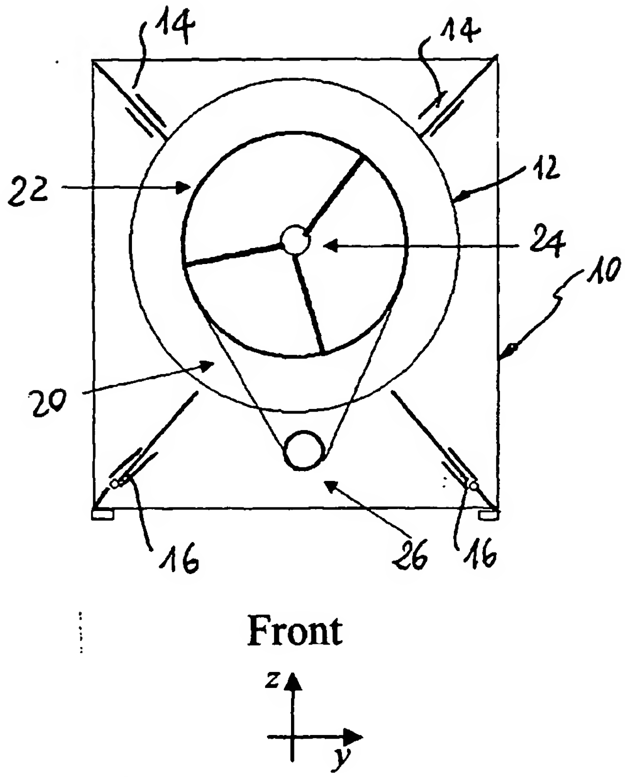

Fig. 1

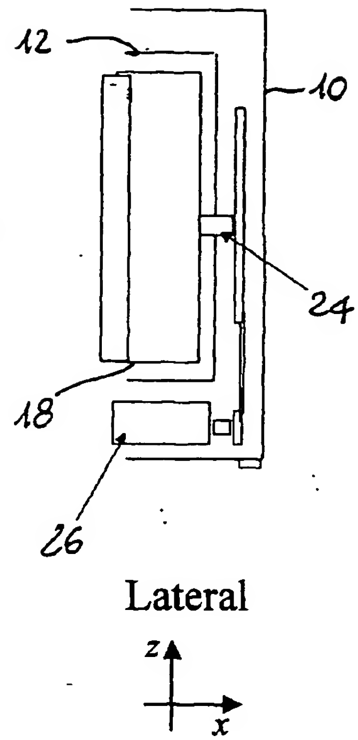

Fig. 2

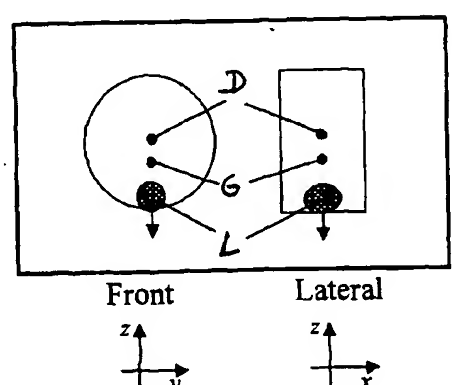

Fig. 3

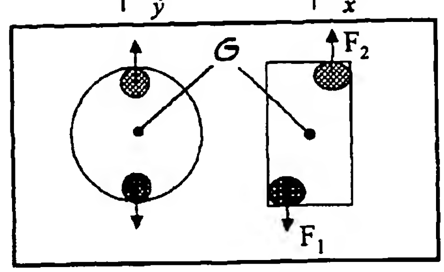

Fig. 4

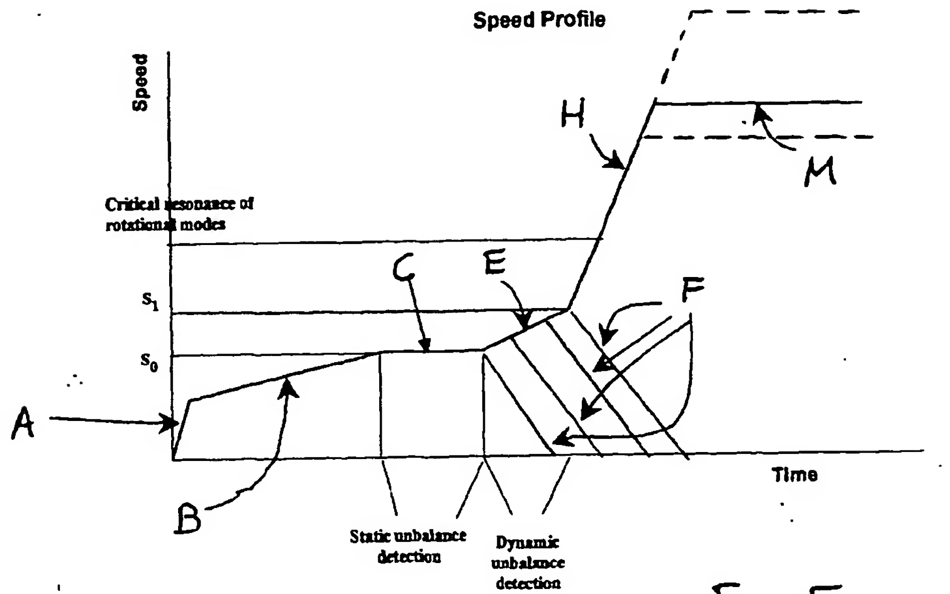
Speed Profile
Speed
Critical resonance of rotational modes
S_1
S_0
A
B
C
E
F
H
M
Time
Static unbalance detection
Dynamic unbalance detection

Fig. 5

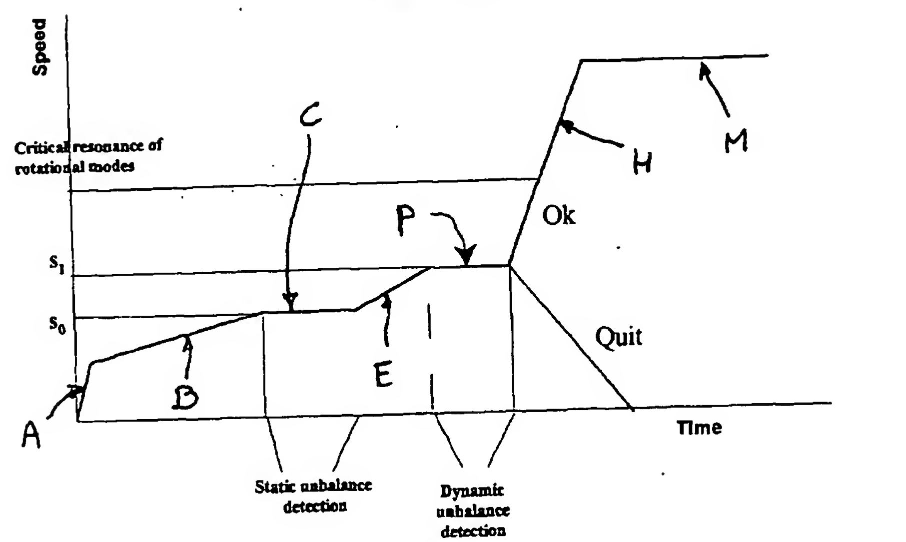
Speed Profile
Speed
Critical resonance of rotational modes
S_1
S_0
A
B
C
E
P
H
M
Ok
Quit
Time
Static unbalance detection
Dynamic unbalance detection

Fig. 6

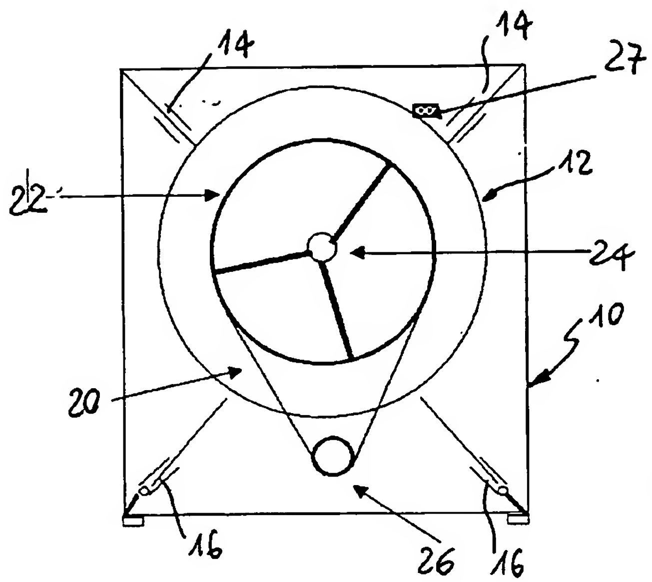

Fig. 7 Front

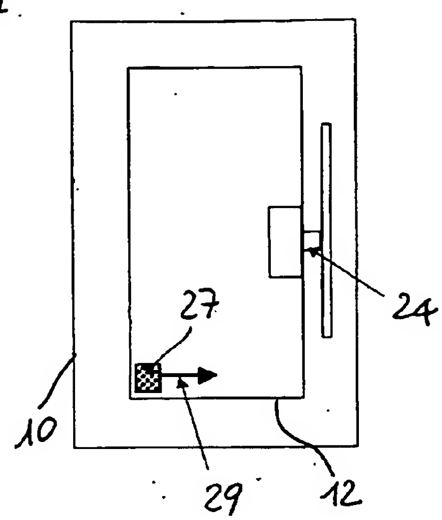

Fig. 8 Top

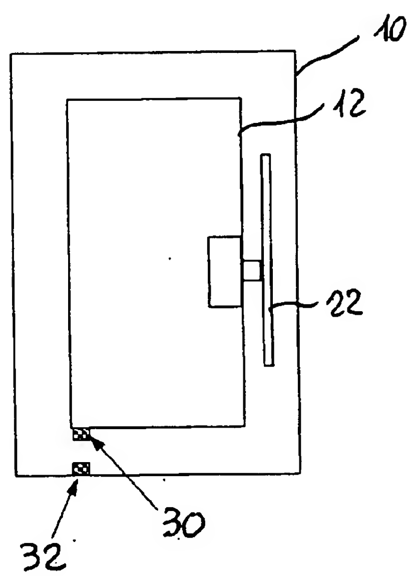

Fig. 11 Top

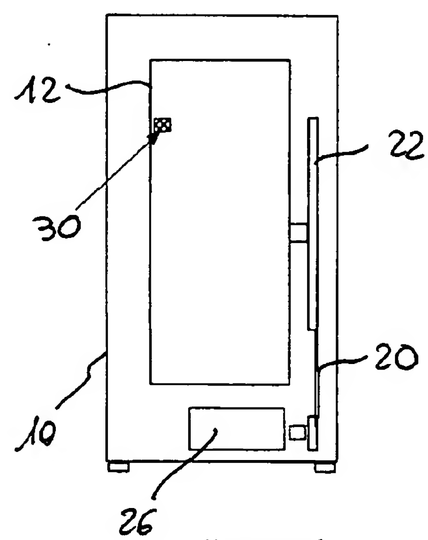

Fig. 12 Lateral

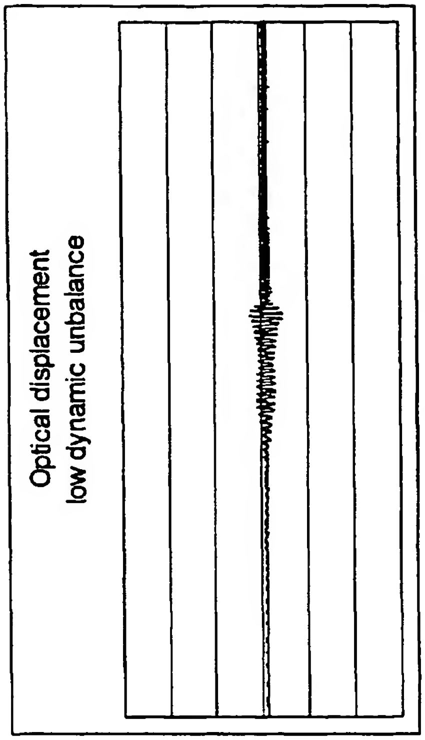

Fig. 13

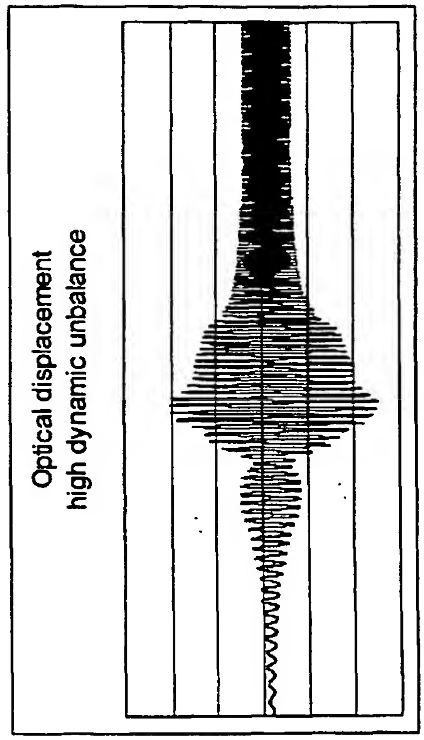

Fig. 14

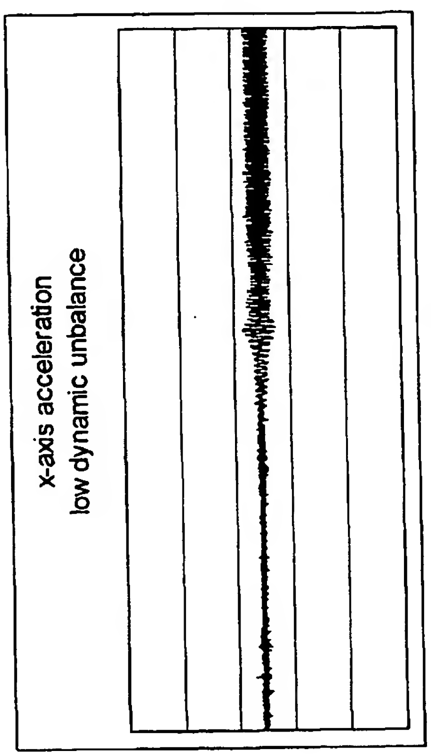

Fig. 9

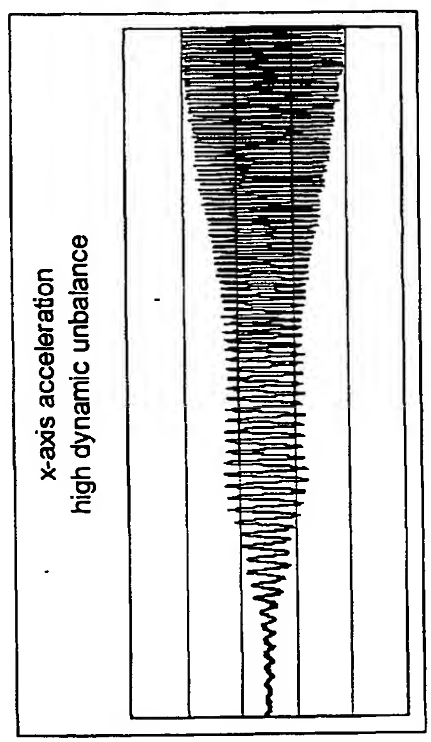

Fig. 10

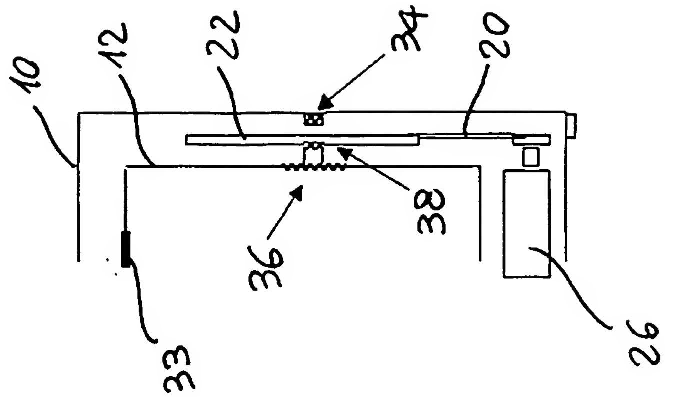

Fig. 16

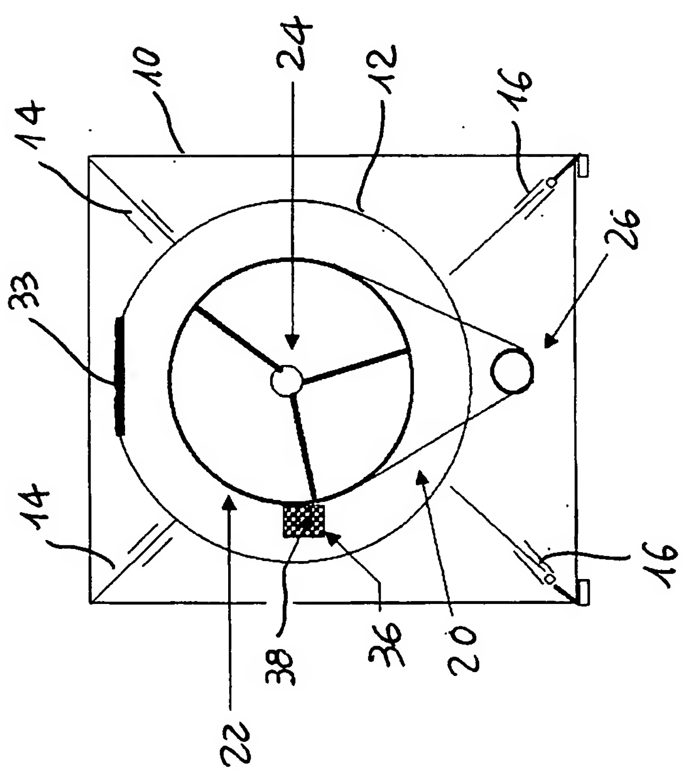

Fig. 15

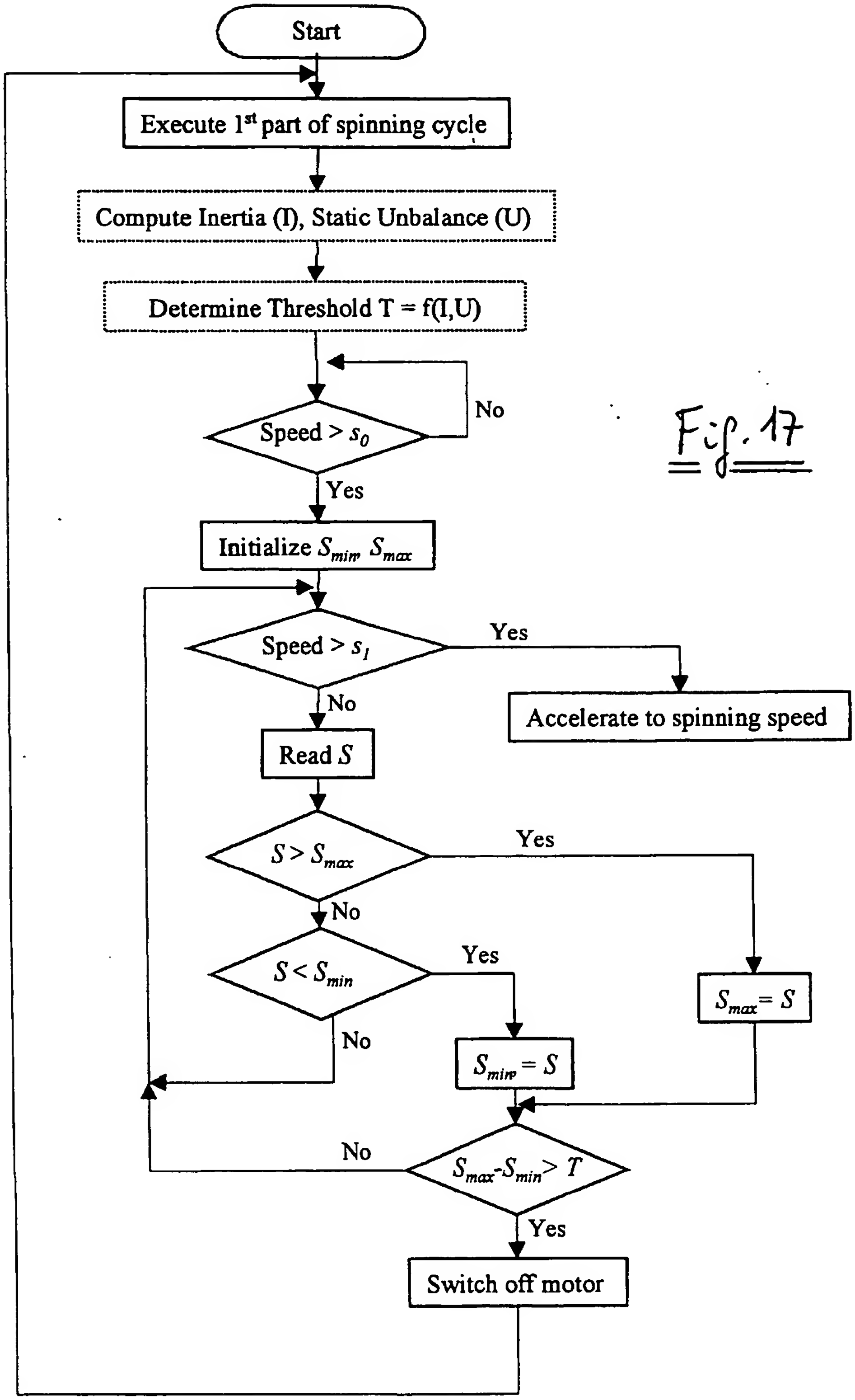
Start
Execute 1st part of spinning cycle
Compute Inertia (I), Static Unbalance (U)
Determine Threshold T = f(I,U)
Speed > s_0
No
Yes
Initialize S_{min}, S_{max}
Speed > s_1
Yes
No
Accelerate to spinning speed
Read S
$S > S_{max}$
Yes
No
$S < S_{min}$
Yes
No
$S_{max} = S$
$S_{min} = S$
No
S_{max}-S_{min} > T
Yes
Switch off motor

Fig. 17

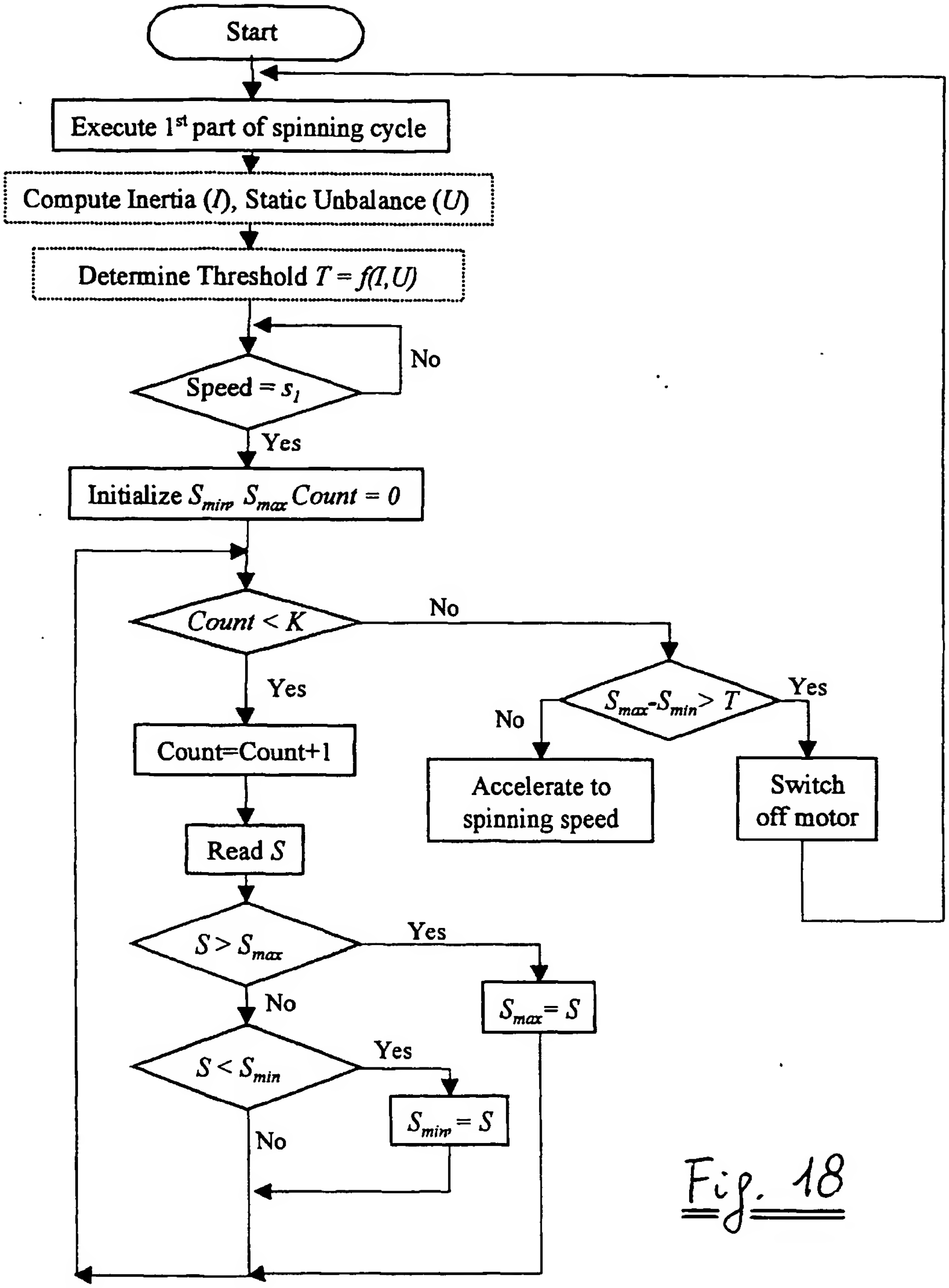
Start
Execute 1st part of spinning cycle
Compute Inertia (I), Static Unbalance (U)
Determine Threshold T = f(I,U)
No
Speed = s1
Yes
Initialize Smin, Smax, Count = 0
Count < K
No
Yes
Smax-Smin > T
No
Yes
Count=Count+1
Accelerate to spinning speed
Switch off motor
Read S
S > Smax
Yes
No
Smax = S
S < Smin
Yes
Smin = S
No

Fig. 18

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 11 3885

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 763 618 A (SHARP K.K.) 19 March 1997 (1997-03-19) * the whole document *	1,3-5, 8-14	D06F37/20
X	EP 0 885 993 A (ELECTROLUX ZANUSSI S.P.A.) 23 December 1998 (1998-12-23) * claims; figures *	1-5,8,9	
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D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 December 2000	Courrier, G

CATEGORY OF CITED DOCUMENTS

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15-12-2000

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